treatments of it are something of an acquired taste, and the two fairly heavy-duty chapters here are no exception. Authors of subsequent chapters tend to focus on their specialism, and then say either how important it is for heterogeneity, or vice versa. A few chapters are on subjects sufficiently mature for the authors to really work the theme. For example, those on the ecology and population dynamics of the large herbivore community show how, over scales from biome down to local and from geological down to seasonal, habitat heterogeneity is a driving force in ungulate speciation and abundance, the size-scaling of ungulate assemblies, and the species richness of savannas. This and other examples show that understanding the effects of heterogeneity remains an important part of the research agenda for the future — a fitting tribute to the first century of research in Kruger. ■

Andrew Illius is at the School of Biological Sciences, University of Edinburgh, Michael Swann Building, Mayfield Road, Edinburgh EH9 3JR, UK.

More on South African environments

South Africa's Environmental History: Cases & Comparisons
edited by Stephen Dovers, Ruth Edgecombe & Bill Guest
Ohio University Press/David Philip, $24.95

Social History & African Environments
edited by William Beinart & JoAnn McGregor
Ohio University Press/James Currey, $49.95 (hbk), $27.95 (pbk)

The Rise of Conservation in South Africa: Settlers, Livestock, and the Environment 1770-1950
by William Beinart
Oxford University Press, £65

Exhibition

Inspired by insects

Observation is key to the work of both artists and scientists. Illustration has been an essential part of scientific research for centuries and the images have often been admired for their aesthetic as well as informative qualities. Not surprisingly, the beauty of biology has also captured the imagination of artists, some of whom borrow scientific techniques as an aid to observation.

Artist Mark Fairnington uses high-definition electron microscopes to photograph insect specimens before he begins to paint them. This enables him to capture on huge canvases minute details of the original, but with subtle manipulations.

Examples of his work, like the mantid depicted here, are on show in *Fabulous Beasts*, an exhibition at the Natural History Museum in London until September 2004. The exhibition also features the work of another artist, Giles Revell, who uses electron microscopy to reproduce majestic monochrome images of common insects. The works of both artists are juxtaposed with specimens from the museum's own vast entomological collection, and a rare glimpse of the first edition of Robert Hooke's *Micrographia*.

Mind the gap

The Physiology of Truth: Neuroscience and Human Knowledge
by Jean-Pierre Changeux (transl. Malcolm DeBevoise)
Belknap Press: 2004. 288pp. $45, £29.95, €41.50

David Papineau

Can neurophysiology cast any light on the human condition? Books that set themselves this ambition, and there are plenty, are invariably disappointing. The problem is not that we lack information at the neuronal level — a great deal is known about cell receptors, neurotransmitters, re-entrant connections and so on. Rather, the difficulty lies in relating this microscopic knowledge to higher human faculties such as thought, emotion and consciousness.

To get round this, popular-science books by the likes of Francis Crick, Joseph LeDoux or Antonio Damasio typically have the following trajectory. We start with a few chapters on the neuronal nitty-gritty. But then the gears surreptitiously change, and we switch to speculation about the mind's higher powers. However, any serious theorizing at this level tends to be 'boxological', rather than physiological — we are given flowcharts connecting posited brain modules, but there is no bottom-up, cell-level account of how these modules might work.

Perhaps this is unsurprising, given the kind of evidence that is currently available about the large-scale operations of the mind. In recent years, functional-imaging data have been added to findings from studies of brain lesions. But even these new data are at too gross a scale: it is like trying to figure out how a computer works by noting when different bits get hot and what goes wrong when certain parts are broken. With luck, this might give us some idea of where certain operations are located, but it is not going to tell us about the mechanisms that make them possible.

Jean-Pierre Changeux's credentials as a neurophysiologist are outstanding. He has been director of the Unit for Molecular Biology at the Pasteur Institute in Paris for more than 30 years, where he has played a prominent role in understanding allosteric proteins and their relevance to neurotransmitter reception. Nor is Changeux any stranger to popular science writing — his *Neuronal Man* (1983) and subsequent book-length dialogues with other prominent French intellectuals have been great successes in his native country and elsewhere. Nevertheless, his new book, *The Physiology of Truth*, suffers from the typical flaws of the genre. Initial chapters concentrate on neurophysiological signalling and modulation, but by the end the topics are knowledge, culture and the history of science. Interesting points are made at both levels, yet the initial neuronal material seems to shed little light on the later large-scale issues.

Still, the book does have the virtue of suggesting a possible, deeper explanation of why the micro–macro gap may be so hard to bridge. Throughout the book Changeux emphasizes the plasticity of the brain. Significant neuronal variation can be found among even simple organisms such as water fleas, and the brains of monozygotic human twins often exhibit striking differences. Changeux sees this variability as a result of epigenetic selection — the genes provide a general 'envelope' for brain development, but the details depend largely on the selective favouring of some spontaneously formed synaptic connections over others during development.

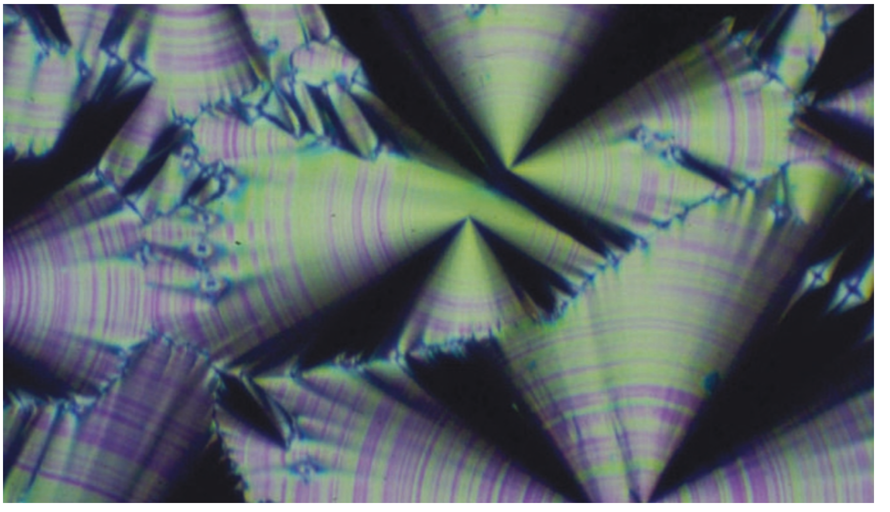
If this neural darwinism is right, then perhaps it is inevitable that any attempt to identify the neurophysiological mechanisms

Science in culture

A fluid definition of art

Viewing images of liquid crystals as art raises complex questions.

Martin Kemp



JOHN GOODBY

When does an image made by a researcher for scientific purposes become art — if at all? Over the ages, the beauty of scientific images has been widely recognized. Reading Robert Hooke's *Micrographia* (1665) gives us a sense of his aesthetic thrill faced with the wondrous images in the new device of the microscope. Like many of his contemporaries, Hooke would have recognized such miracles as the eye of the fly as the product of God's, or nature's, artistry. But does this mean that they are works of art in the normal sense of the term?

The question is implicitly raised by many of the striking products of modern scientific imaging techniques. And it is overtly posed by the claims of chemist John Goodby of the University of Hull, UK, that his microscopic images of liquid crystals (shown here) are "every bit as good as the kind of art you see in most galleries". Leaving aside the question of what is meant by "good" (and good for what?), his decision to start exhibiting his pictures as works of art plays into a complex series of shifting definitions of art in the modern era.

Until the twentieth century, the issue would not have arisen within the institutionalized definitions of art and science in post-Renaissance Western culture. But when artists decided to display everyday objects in art galleries — such as the signed urinal entitled *Fountain* by Marcel Duchamp in 1917 — the definition of art became very wobbly. The exhibiting of such 'ready-mades' and their enshrining in galleries and museums, in the collection of Duchamp's works in Philadelphia, for example, leaves us with a definition that extends little beyond the claim that anything is art that an artist claims is art — as is anything that viewers can look at as art.

Goodby's claims are of course more specific than merely saying that because he exhibits the liquid-crystal pictures as art, then they are art. He is implicitly setting his images in the context of modernist abstraction, in which paintings or sculptures are devoid of figurative subject matter and narratives. Indeed, the way that the great masters of abstraction have transformed what we are prepared to consider as art has radically enhanced our ability to appreciate the marvellous natural configurations revealed by modern scientific techniques.

The amount of artistic contrivance in Goodby's images far exceeds that in Duchamp's urinal. The selection of certain liquid crystals at certain stages in their intermediate state between solid and liquid, the setting up of the microscope to deliver certain visual qualities, and the choices involved in rendering and printing the pictures (regarding colours, textures, plasticity, scale and framing, for example) are all done to create the best effect. This is to say nothing of the way Goodby collages his images to produce images of birds and flowers.

I wonder how many scientists who use visual images prominently in publishing their work have not made some kind of aesthetic choice at some time or other. Certainly anything that features on the cover of *Nature*, in its current format, is designed to attract attention in ways that are comparable to the use of a painting on the cover of an art journal.

In the final analysis, should we worry about whether something is art or not? If it excites us, isn't that enough? My answer is drawn from a long historical perspective. The set definition of art as an aesthetic product devoid of practical function is actually comparatively recent (dating back to the late eighteenth century) and is limited to Western and Westernized societies. The art world has performed increasingly unconvincing conceptual gymnastics to accommodate everything that artists have recently thrown at it. If we stop being bothered by the question of whether something is art, and instead respond openly to the visual products that we are capable of making, we will be able both to agree with Goodby that his works are as 'good' as art, and say that any implicit competition between artists and scientist as makers of wonderful images is rather beside the point.

Martin Kemp is professor of the history of art at the University of Oxford, Oxford OX1 1PT, UK, and co-director of Wallace Kemp Artakt.

behind higher cognitive faculties will end in failure. Maybe there simply aren't any such mechanisms to be found. This is the view of 'functionalists' in cognitive science. They believe in large-scale patterns in human thinking of the kind portrayed in the familiar flowcharts, but they deny that there are any uniform physiological mechanisms to explain those regularities. Not that they assume any kind of spooky magic; rather, they argue that different mechanisms will underpin the regularities in different people.

From the functionalist point of view, asking about 'the physiological mechanism' responsible for scientific reasoning — to take a topic from the end of Changeux's book — is like asking for 'the low-level explanation' of why all word-processing programs work in roughly the same way. In truth, there isn't any one such explanation. Different programmers use different tricks, subject only to the constraint that their programs end up doing what word-processors have to do. Similarly, neural darwinism may ensure that our brains use different tricks to achieve roughly the same ends, subject only to the constraint that we all end up getting around in the world reasonably well.

Changeux has plenty to say about neural darwinism, and touches on functionalism in passing, but he doesn't quite spell out the connection between them. Still, his book presents a more satisfying picture of the brain than most of its competitors in this crowded market. On standard accounts, it can simply seem frustrating that we never get any bottom-up explanations of higher cognitive functions. If the structure of the brain is laid down by a definite genetic plan, then why can't we find out about the underlying mechanisms? Changeux's book fails to identify any such mechanisms too, but at least he gives us some insight into why the search for them may be doomed to permanent frustration. ■

David Papineau is professor of philosophy of science, King's College London, The Strand, London WC2R 2SL, UK.